FIT-4-AMANDA – AUTOMATION OF PEMFC-STACK MANUFACTURE

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Abstract: An EU-funded project Fit-4-AMandA aims to establish a technological roadmap to scale-up from less than hundred stacks/year (manual assembly) to 50,000 stacks/year (automated assembly) in 2020 and beyond. Existing membrane-electrode assembly (MEA) and stack were redesigned/adapted for manufacturability and automation. The technology and machine system for the automated assembly of polymer-electrolyte-membrane fuel cell (PEMFC) stacks were developed, manufactured and are currently being tested. Fast in-line non-destructive quality-assurance methods for automated production of MEAs and stack assembly are being developed and implemented. For the final period of the project, a validation of the designs, hardware, tools and software for the automated production of MEAs and stack assembly as well as an integration of one of the prototype stacks manufactured by the automated processes into a light-commercial vehicle followed by a field-testing are scheduled.

KEYWORDS: FUEL CELLS, MASS MANUFACTURING, AUTOMATION, PEMFC STACK, MEA, BIPOLAR PLATE, SINGLE CELL, QUALITY CONTROL, SINGLE-CELL CHARACTERISATION

1. INTRODUCTION

The main objective of the Fit-4-AMandA [1] project is to build an automated manufacturing line (including in-line non-destructive tests) capable of ramping up the production of PEMFC stacks. To be optimised for automated manufacture, the current design of PEMFC stacks and stack components underwent necessary modifications. Furthermore, a demonstration of the resulting mass-produced stacks is to be performed in real environment, i.e., one of the stacks is to be integrated into a light commercial vehicle (LCV) and tested in day-to day operation.

The project offers the mass-production machine innovative solutions, which affect processes, products and tools with the objective to bring the Manufacturing-Readiness Level from MRL5 (Capability to produce prototype components in a production relevant environment) to MRL7 (Capability to produce systems, subsystems or components in a production representative environment).

1.1. Facts & figures

In the scope of the project, a mass-manufacturing machine (MMM), schematically depicted in Fig. 1, with an automation grade of more than 90 % was developed. The MMM is capable of producing ready-to-operate fuel-cell stacks in one assembly line at a theoretical throughput of 5000 – 10,000 stacks/year (depending on the stack size). The technology of the MMM reduces the production time from the current 40 hours per 96-cell stack (manual assembly) to 30 minutes per 96-cell stack (automated assembly).

Fig. 1: Fit-4-AMandA design of the Mass-Manufacturing Machine (MMM) [1]

1.2. Potential adopters of technology

The Fit-4-AMandA project results in two major products: an MMM described above and a fuel-cell stack, which was redesigned and optimised for the automated manufacture. The MMM would be of interest mainly for the fuel-cell stack manufacturers that want to upscale their production volume. Typical customers for the optimised stack are, especially after the integration into said Light-Commercial-Vehicle and the field-testing, delivery and logistics companies and postal services.

2. CHARACTERISATION OF SUBASSEMBLIES AND FAST IN-LINE QUALITY ASSESSMENT

The development of non-destructive quality control (NDT-QC) tools for the stack-assembly machine is vital to increase yield and reliability of the mass-produced fuel cell stacks. Low throughputs together with high number of faulty produced stacks – every tenth stack is faulty and needs to be reworked [2] – are among the main technical barriers in the fuel cell stack manufacturing. Additionally, fast quality-testing techniques are lacking [3]. The goal of Fit-4-AMandA project is to elevate these constraints, and fast NDT-QC methods are necessary to do so.

The in-situ diagnostics of single cells and short stacks serves to validate the Fit-4-AMandA cell design. The in-situ diagnostics of single cells involves a scale-up comparison study of single cells with active areas of 25, 50, and 409 cm² (so-called full sized cell). The performance of single cells will be evaluated using selected performance tests (e.g., polarisation-curve measurement and electrochemical impedance spectroscopy) to gauge the impact of scale-up on the cell performance.

The performance of 5-cell stacks, which are not the focus of this paper, will be evaluated independently by PM and TUC to assess, whether the stacks manufactured by MMM comply with the PM standard (i.e., pre-Fit-4-AMandA design).

2.1. Quality control of fuel-cell component

There are three levels of a non-destructive quality control (NDT-QC): a component level (QC of fuel cell components such as half plates, GDLs, membranes, or gaskets), a sub-assembly level (QC of MEAs, BPPs, or single cells), and a stack level. In the project, the following assumption has been made: if the stacking machine handles healthy units (components and sub-assemblies) and can keep the tolerances, the assembled stacks should perform according to the specification. To assure that healthy units are entering the stacking process, a 100-% inspection is necessary meaning every entering unit is tested not just a random selection of units. In addition, NDT-QC methods have to be fast enough otherwise they create so-called bottlenecks, i.e. limitations of the overall throughput of the manufacturing process.

The critical entries into the stacking process are bipolar plates (BPP) and membrane-electrode assemblies (MEA). The assembly of MEA is currently not part of the MMM; therefore, the QC of MEAs is to be performed on the MEA supplier side. After consulting the available literature as well as gathering the experience of the industrial partners (Aumann, PM and IRD), the following tests were focused on:

- integrity and tightness tests of every BPP,
- tests of the MEA for defects typically occurring after hot-pressing,
- in-process and post-process quality control (QC) of sealings in the stack.

The method selection was optimised to minimise the measuring time allowing the stacking process to reach its maximum throughput. Among considered QC candidates are for example machine-vision systems and infrared (IR) thermography. Potentially hazardous QC methods such as X-ray radiography were excluded. The MMM is modular and therefore it can be retrofitted with additional modules (e.g., for QC or additional stacking modules; see greyed modules in Fig. 2) using only minor changes in its configuration.

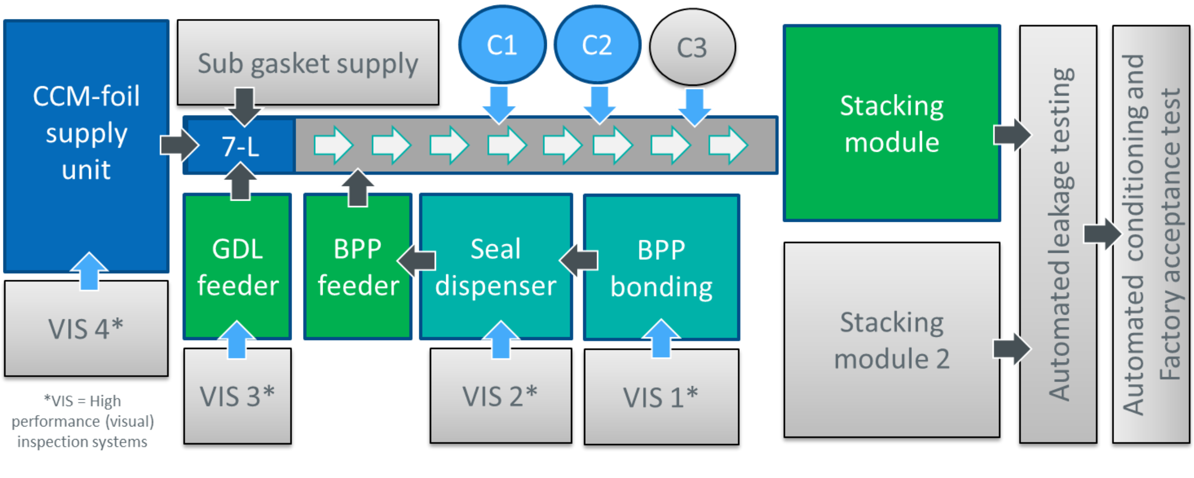


Fig. 2: Modular character of MMM (greyed modules show possible expansion)

2.2. Scale-up study

As mentioned above, the tested single cells are of 25, 50, and 409 cm² active area.

2.2.1. Characterisation of small single fuel cells

The 25 and 50-cm² cells are tested using a standardised testing harware (see Fig. 3), which allows testing under fully reproducible test conditions and contact pressure that can be regulated directly using pneumatic actuator.

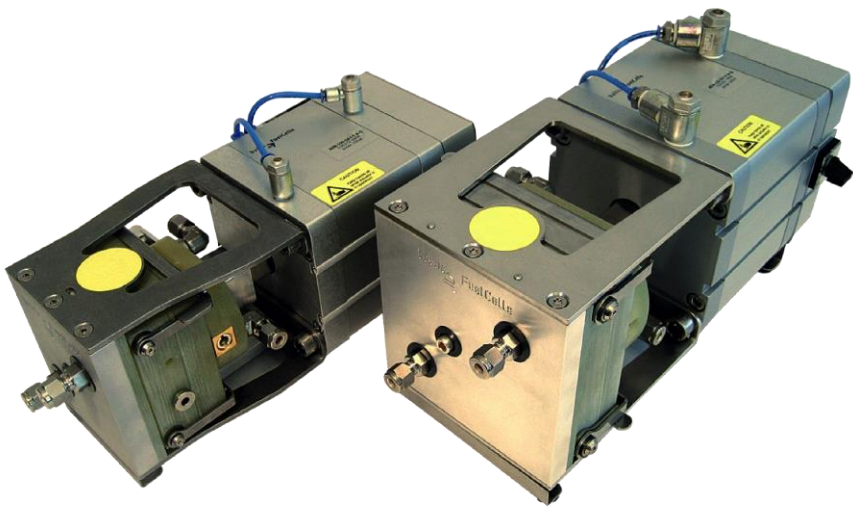


Fig. 3: Support frame pressure units with corresponding cell fixtures (25 and 50 cm²) from the company balticFuelCells [4]

2.2.2. Characterisation of full-size single cells using zero-voltage loads

Single cells with large active areas (>400 cm²) are low-voltage (<1 V) power supplies that provide high current (>400 A @1 A/cm²). Such a combination posses a challenge for instrumentation in particular the electronic loads used to sink the generated current. Most electronic loads use power transistors (see Fig. 4) that act as variable resistors to regulate the current flowing into the load. Under high currents, such loads have a limited operation between 0 and 3 V, because the transistor is turned on to full saturation and can no longer regulate the current.

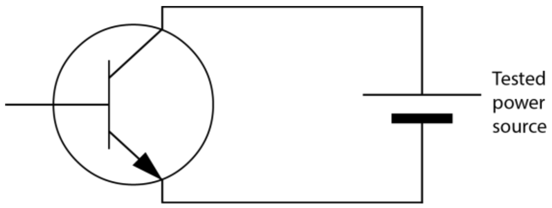


Fig. 4: Simplified diagram of a typical electronic load

One of the solutions to this problem is connecting an auxilary boost power supply in series with the electronic load and the power supply. Such an electronic load, so-called zero-voltage load (block diagram shown in Fig. 5), was developed by company Kolibrik according to specification provided by Fit-4-AMandA. A prototyp is scheduled for testing with the Fit-4-AMandA full-sized single cell with an active area of 409 cm².

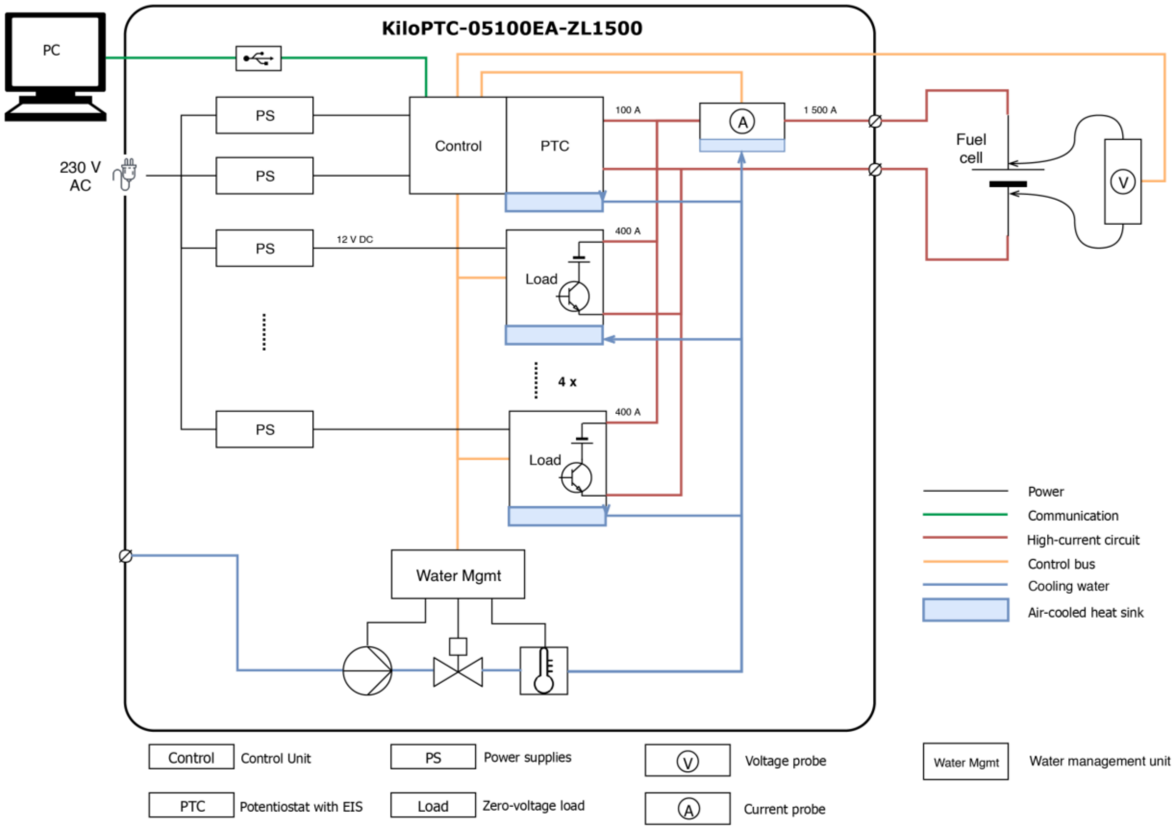


Fig. 5: Block diagram of zero-voltage load (KiloPTC-10100EW-ZL1500 model) [5]

3. RESULTS AND DISCUSSION

The selection and implementation of the QC methods is still ongoing. In case of BPPs, to measure large sample areas (see Fig. 6) using an optical method without compromising in measurement resolution poses a great challenge. A compromise has to be found. In Fig. 7, an example of a successful detection by Keyence's line-scan camera is shown.

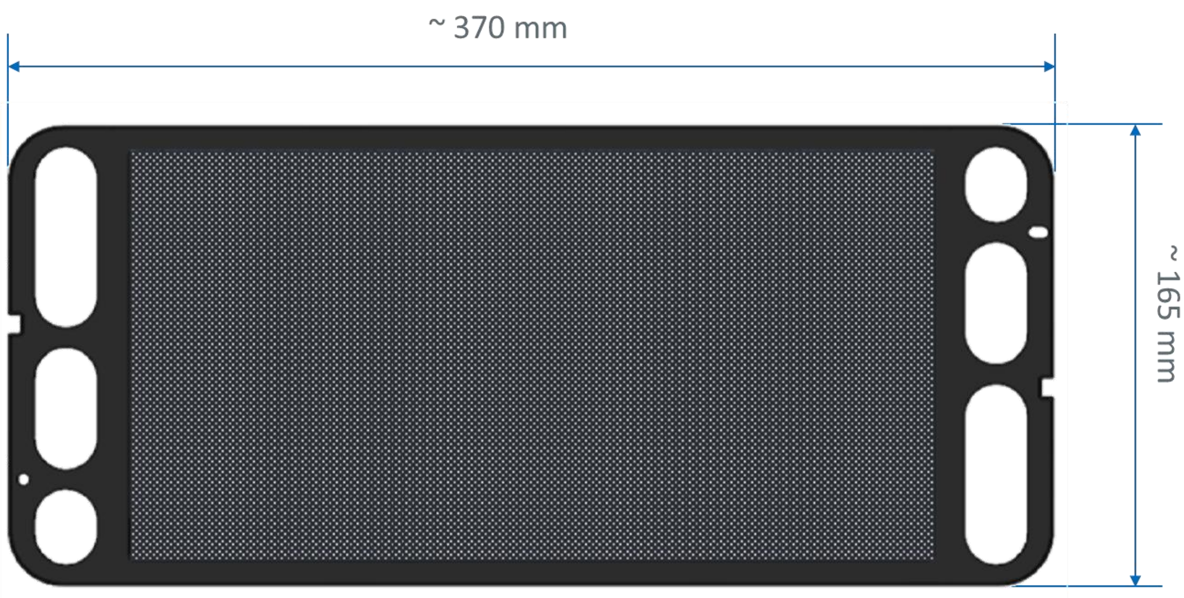


Fig. 6: Fit-4-AMandA bipolar plate (flow field is omitted for confidentiality reasons) [6]

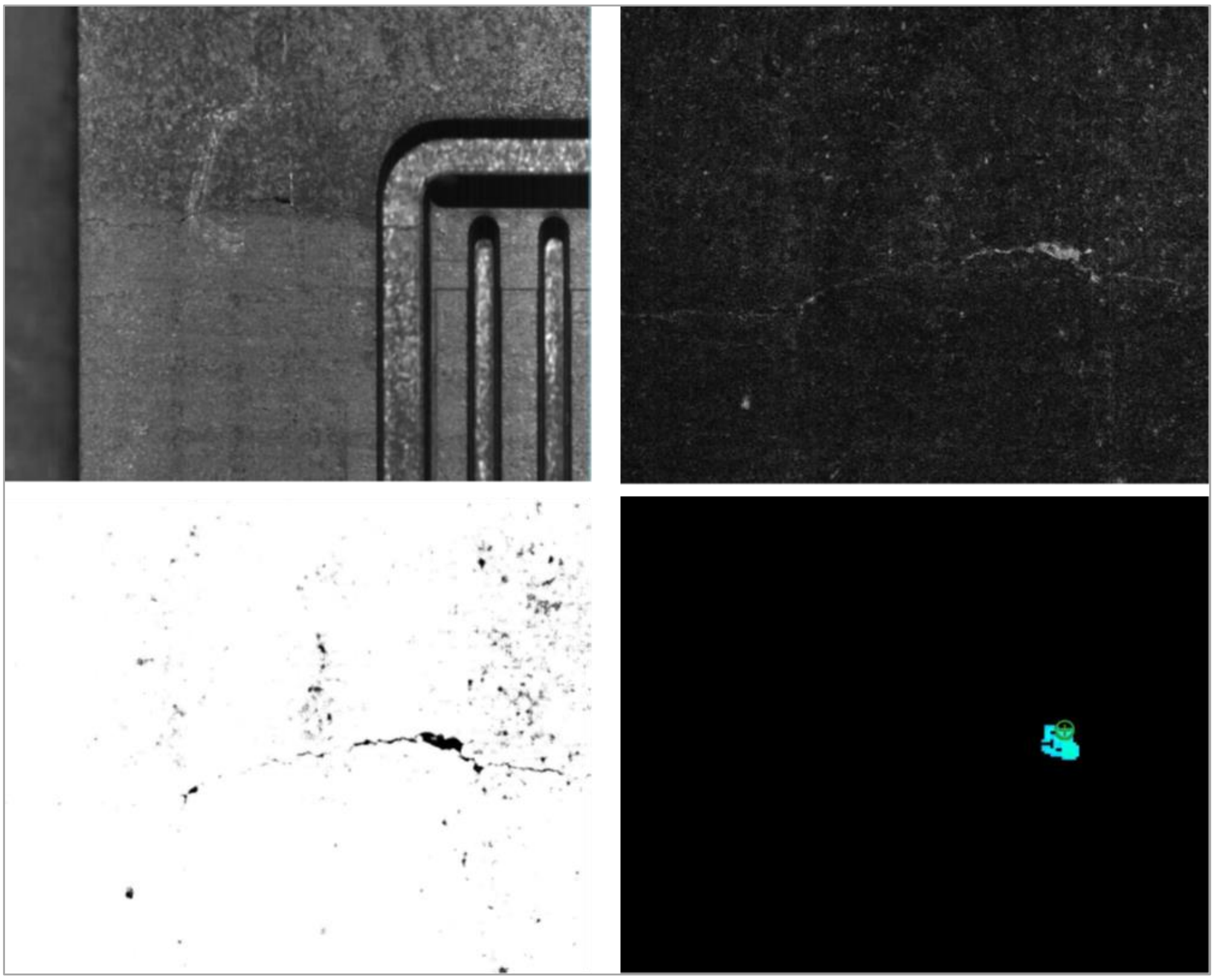
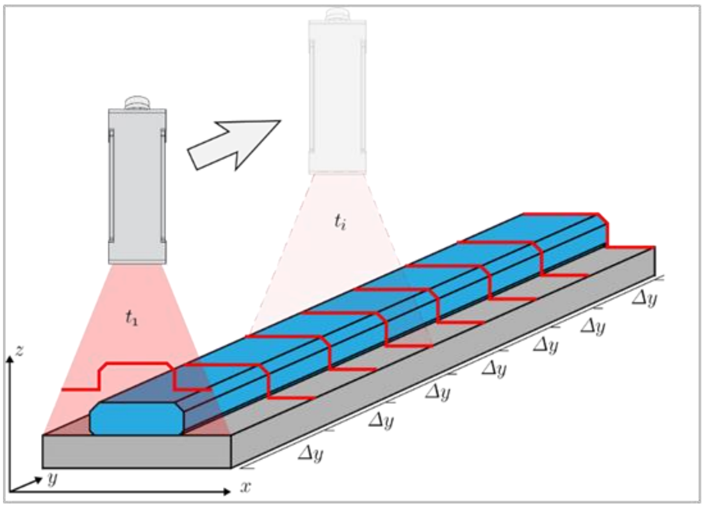


Fig. 7: Upper left, a normal picture from a line-scan camera; upper right, a magnified hair crack; bottom left, magnified hair crack after image processing using filters; bottom right, a hair crack (wider part) successfully detected.

The current results of performed sealing QC tests show that a colour additive for the sealing material is necessary (see Fig. 8). Assuming a non-transparent sealing bead, an in-process QC of the sealing bead supports a dispensing speed of over 100 mm/s.



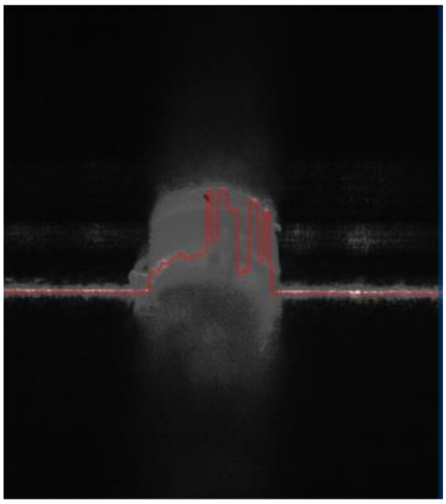


Fig. 8: On the left, an illustration of the scanning process using a 3D profiler; on the right, a first test with Keyence.

4. CONCLUSION

The project Fit-4-AMandA is nearing its conclusion. The MMM, which was developed, build and commissioned, offers a possibility to scale-up the production of PEMFC stacks and in so help to reach the EU target of 50,000 stack/year.

The presented overview contains a selected set of the project results to demonstrate the capabilities of the developed QC methods. Moreover, the single cell study, including the testing of large-area single cells using a zero-voltage load technology, will provide better understanding of the impact of the scale-up of the single cell on its performance.

For more of publicly available results, the reader is referred to the project website.

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